IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

# A performance evaluation of single basin double slope passive solar still using different materials as storage medium

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***Abstract:*** **In this study, various methods of desalination such as direct and indirect have been discussed. This study shows the performance analysis of solar still with different storage substances at different depth of water. The comparison of productivity and thermal efficiency for solar still having water with jute, aluminum chips, granite, a conventional still and a non-conventional still have been conducted. The analysis and compilation of results have done and concluded that the maximum efficiency and productivity is obtained from jute in comparison to aluminum pieces, granite, saline water in conventional still and saline water in non-conventional still, i.e. 15.69 % respectively. It is observed that the jute act as a best storage material among all to get maximum efficiency and productivity of single basin double slope passive solar still.**

***Index Terms*** **– Solar energy, material, solar still, temperature, heat transfer, productivity.**

## I. Introduction

The degree of development of the country is measured by the scale of utilizing of energy for human survival. The world is finding alternatives of energy to fulfil the energy needs. As country grows and develops the gross domestic product (GDP) increases and almost proportional to the energy consumption [1]. Human development index (HDI) of India is very low, as compared to other countries. But, it is assumed that it will increase in upcoming years. Energy intensity is defined by the ratio of energy consumption to GDP. This factor is higher for developing countries in comparison to developed countries [2].

There are various methods to purify water and can be classified into four main categories such as follows, separation, filtration, chemicals, oxidation. There are five types of contaminants and impurities that are found in water i.e. bacteria, particulates, chemicals, minerals, and pharmaceuticals. Methods existing to remove these elements ranges from simple, cheaper and inexpensive to elaborate and costly. Often used in the production of pure potable water, several techniques must be combined in a particular sequence. There are various methods available to purify water, the settling down of heavy suspended materials by the action of gravity is known as sedimentation. Another process includes heating water for 15 to 20 minutes which kills 99.9 % of all microorganisms and vaporizes most chemicals impurities which are dissolved in the water. Distillation involves the process in which water boils and recondenses, but in output water, many chemicals are vaporized and recondensed in concentration [3-4].

Generally, Single basin double slope solar still is used to convert waste water into pure one. It is the most popular device used for filtering water with the help of solar energy which induces heat transfer. Solar still is a device which is sealed and contains brine in its shallow basin. The process of desalination through solar still is the cheap & effortless [3]. Black pane is used at the inner surface to reduce heat transfer losses. The black color painted on the absorber plate absorbs the utmost part of the transmitted radiation. Due to heat generated at the absorber plate, the brine gets heated and at a particular temperature it starts evaporating and condensed at the inner surface of glass cover plate. Due to the action of gravity, the condensed water slides down along the surface of cover plate and then collected in a measuring flask with the help of two outlet valves present over the side of the basin. The collected water can be used for drinking and other purposes [5].

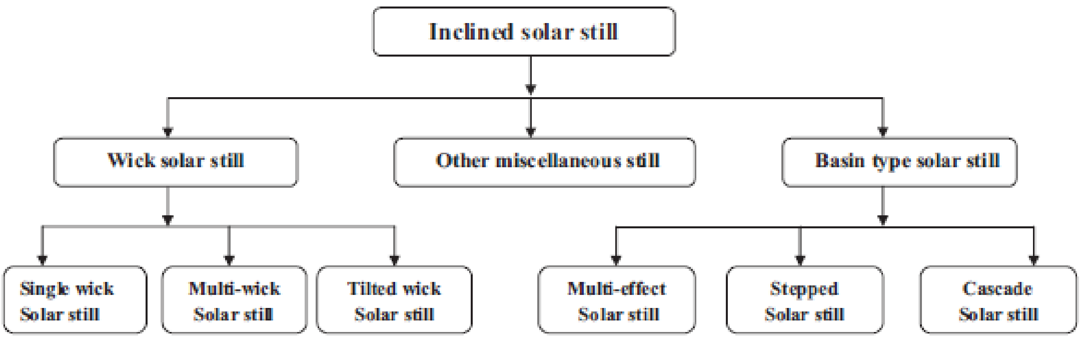


Figure 1 Classification of inclined solar still [4]

The two major challenges for human society today are shortage of fresh water and shortage of conventional energy. Solar still is the best method to convert saline, brackish water into fresh water using the unconventional source of energy which is freely and abundantly available in planet earth. The low productivity is a major drawback with conventional basin still. The most important is design parameters like optimization of glass inclination, absorber plate area, and free surface area of water and depth of water. The main difficulty in conventional still is maintaining minimum depth and large surface area of water. Inclined solar still is alternative to increase the surface area of water and maintain minimum depth [5, 6]. The researchers have put efforts to develop various designs of inclined solar stills to maintain the minimum depth of water using wicks, steps in the stills to increase the productivity.

Renewable-energy-based desalination is the promising solution to both shortage of fresh water and shortage of convention energy [8]. The solar still is very old technique that has been in use for few hundreds of years. Conventional basin type solar still is very simple in its design and it can be easily fabricated with locally available material and it requires less maintenance. It consists of basin covered with a transparent cover. Inside surface of basin is normally painted with black color to absorb maximum solar heat. Brackish or saline water is kept in the basin and it is exposed to solar radiation. Thus, water is slowly evaporated and it get condenses as it comes in contact with the basin cover. This condensed water is collected separately by separate channels as a distillate [6, 7].

In DSSS, the cover plate plays the role of condenser and also known as condenser plate. It may also be considered as thermally self governing plates. The inclination & location of solar still are the consequences in a direction followed by the sun. Therefore, absorption and transmission amount of energy differs. The orientation of still and time of sun exposure are the parameters that play a vital role in the working of solar still or these are the responsible factors for the productivity [9, 10].

The storage materials have been used to increase the productivity. In this project, jute aluminum chips and granite are used as the storage material in different still and all the readings were taken. The main objective of this research is to evaluate the performance analysis of single basin double slope passive solar still using different material and determination, compilation and analysis of the results obtained from experiments.

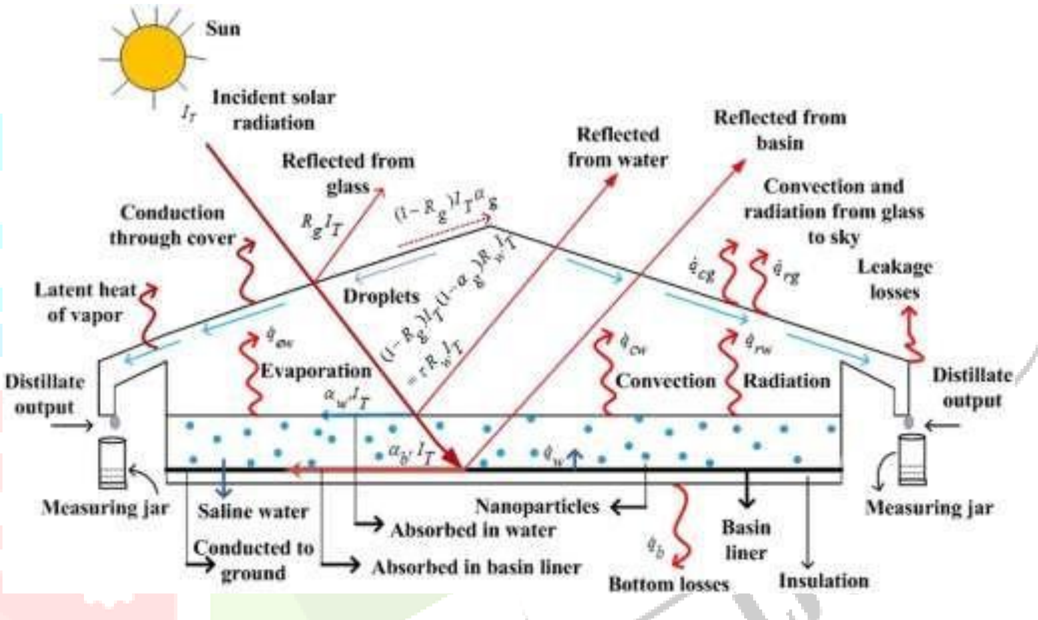


Figure 2 Rare view of solar still showing Opaque triangular section [7]

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## II. LITERATURE REVIEW

Various high and medium technologies have been developed for water purification such as reverse osmosis (RO), multi-stage flash distillation (MSF), multi-effect distillation (MED), vacuum distillation, and vapor compression. But solar distillation is a simple technology which utilizes solar energy (an ample source of non-conventional or renewable energy). It is an economical, effective and environment friendly technology. The most simple and least expensive solar stills are passive solar stills.

Zakaria Haddad et al. [1] proposed a still, consists of mainly a basin type, single slope solar still in which the VRW is integrated against the rear side of the still. The basin area of the still is 0.36 m2 (0.9 m × 0.4 m) fabricated using 1.0 mm thickness galvanized iron and painted with black spray paint to increase solar ray's absorption. The basin is placed inside a rectangular wooden box of 4 cm thickness and the bottom space between them is filled by 8 cm of glass wool to reduce bottom thermal losses. Kamel Rabhi et al. [2] modified single-basin single-slope solar still. A pin fins absorber and a condenser are integrated in the modified solar still. A detailed still design and still functioning description is carried out. An experimental comparative performance study is conducted between the conventional still, the still with condenser, the still with pin fins absorber and the still with both condenser and pin fins absorber. A gain of water production in the order of 32.18% is recorded for the still with condenser (using air flow and external condenser) compared to the conventional still. For the case of the still with simple pin fins absorber, the water production gain is only 14.53% compared to the conventional still. Ravishankar Sathyamurthy et al. [5] determined the effect of integrating solar still, improves the yield of fresh water from both solar still. A constant gravity feed method was used to cool the cover of tubular solar still and the extracted heat by the water is sent to the basin of pyramidal solar still. The heat extracted from the solar still (Tubular) was utilized for evaporating water from the single basin pyramidal solar still. Experimental results also showed that the flow rate of water for cooling the external cover of the tubular solar still is limited from 10 to 100 ml/min as the extraction of heat from the cover was minimum at increased mass flow rate. P. Vishwanath Kumar et al. [11] presented a detailed evaluation of all the solar stills both single and multi-effect type with passive and active configuration is obtainable. The present reading aims at telling the design stipulation and stress the qualities and demerits of a variety of solar stills upon which study has been done till recent past. Also a discussion on prospect scope is given with some recommendations in the field of solar stills enhancement to economically produce sustainable drinkable water. A. K. Sethi1 et al. [12] examined the heat transfer coefficient of a new design of solar still known as "Double slope active solar still under forced circulation mode" have been designed by using the Dunkle thermal model and Kumar and Tiwari model. For the nearby study, double slope active solar still was planned and fabricated. In this, DC water pump has been used between solar still and included flat plate collector to re-circulate the water through the collectors and transfer it into the solar still. Experiments have been conducted for 24 hours during May 2012 beyond at dissimilar water depths in the basin (0.03, 0.04 and 0.05 m) of solar still. It was pragmatic that convective heat transfer coefficient between water and inner condensing cover depends significantly on the water strength in the basin.

## III. Methodology and Experimental Setup

The experiment is done in environment condition of BHOPAL city having $77^0$ 36" E $23^0$ 16" N in the month of June 2017. This double slope single basin solar still includes the basin area of $1\times0.5$ $m^2$ with the two inclined faces having inclination $15^0$ each. The experimental setup consists of five components i.e. solar still, thermocouple, sun meter, temperature indicator, measuring flask.

The placement of solar still is key here, the side with transparent glass section is placed facing South direction while the opaque triangular section must face north. The actual picture of experimental setup is shown in fig below:

Figure 3: Experimental setup of non-conventional double slope solar still

The thermocouple used here for measuring temperature at different parts of still is K- type thermocouple. The thermocouple works on the principle of seebeck effect according to which "When two dissimilar metals are joined to form two junction and both the junctions are kept at different temperature then a voltage is induced in the circuit" this voltage can be used to calculate/measure the temperature of hot section. The thermocouple helps in plotting the temperature distribution at different sections of the still. To measure the intensity of incident solar radiations during the experiment sun meter is used. The intensity of solar radiation affects the amount of distillate produced by the still. It generally varies as directly proportion with the intensity of radiation [13, 14].

Figure 4 Conventional still with saline water

## IV RESULT AND DISCUSSION

Experimentation was carried out during sunny days of 13th, 14th and 15th June between 8:00 am to 8:00 pm. The experiments were carried out at 1 cm, 2 cm and 3 cm depth of water in 13th, 14th and 15th June respectively at five different solar stills. One is conventional solar still which slope is arranged along length wise and other four stills are modified stills which slope were arranged along width wise. First day in the case of normal glass cover, the water was collected in majoring jar through outlet valve with 1 cm water level: collecting 630 ml in conventional still, 600 ml in modified still with only saline water, 860 ml in granite, 840 ml in case of aluminum, 880 ml in case of jute. In the second day, the condensate collected at 2 cm depth of water is 570 ml in case of conventional still, 570 ml in modified still, 820 ml in granite, 815 ml in aluminum still and 840 ml by using jute. Last day, the experiments were carried out at 3 cm depth of water and the amount of condensate by using different material as: 505 ml through conventional still, 520 ml through modified still, 790 ml by using granite, 790 ml by using aluminum pieces and 825 ml by using jute with saline water. In all three days, the solar intensity was also measured at time interval of an hour between 8:00 am to 8:00 pm. First day, the maximum solar intensity was 1150 W/m² at 1:00 pm. Second day, the maximum solar intensity was 1157 W/m² at 1:00 pm and the last day maximum solar intensity was measured 1248 W/m² at 1:00. For measuring the temperature, the k type thermocouple wire with digital display unit was used and these were placed at 4 different points for measuring temperature and another one thermocouple point was arranged to measure the ambient temperature.
Where,
$T_1$ = Bottom surface temperature with black body, $T_2$ = Air temperature inside the solar still, $T_3$ = Inside glass surface temperature
$T_4$ = Outside glass surface temperature, $T_5$ = Atmospheric temperature,

Latent heat of vaporization of fluid (L) = = $2.4935\times10^{6}[1-(9.4779\times10^{-4}\times(T_2)+1.3132\times10^{-7}\times(T_2^{2})-4.7974\times10^{-9}\times(T_2)^{3})]$ (4.1)
;for $T_2 < 70^oC$

$$\text{Efficiency } (\eta) = (M \times L)/(A \times I) \quad (4.2)$$

Where, M = yield in Kg/s, A = Area of base of still in $m^2$, I = Intensity of radiation in $W/m^2$

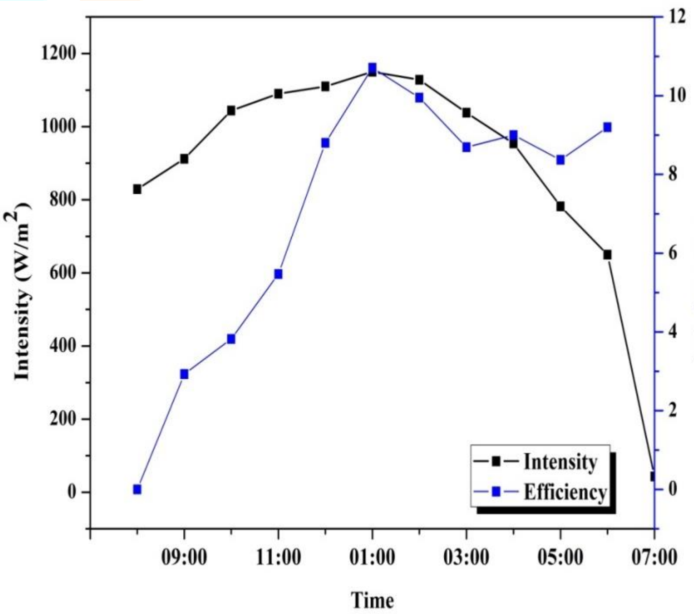


Figure 5 Variation of efficiency and solar radiation with respect to time at 1 cm depth of water

**Table 1**

| Time | I | T1 | T2 | T3 | T4 | T5 | Yield | Efficiency |
|---|---|---|---|---|---|---|---|---|
| Hr | W/m2 | °C | °C | °C | °C | °C | ml | % |
| 08:00 | 829 | 29 | 28 | 31 | 30 | 30 | 00 | 00 |
| 09:00 | 912 | 33 | 35 | 34 | 33 | 32 | 20 | 2.93 |
| 10:00 | 1044 | 38 | 40 | 40 | 38 | 34 | 30 | 3.82 |
| 11:00 | 1090 | 42 | 44 | 43 | 41 | 35 | 45 | 5.47 |
| 12:00 | 1110 | 59 | 62 | 58 | 49 | 36 | 75 | 8.80 |
| 01:00 | 1150 | 62 | 64 | 59 | 50 | 38 | 90 | 10.71 |
| 02:00 | 1128 | 58 | 60 | 56 | 48 | 38 | 85 | 9.95 |
| 03:00 | 1038 | 48 | 50 | 49 | 43 | 37 | 75 | 8.69 |
| 04:00 | 954 | 44 | 48 | 45 | 40 | 36 | 65 | 9.00 |
| 05:00 | 782 | 42 | 45 | 41 | 38 | 33 | 50 | 8.37 |
| 06:00 | 650 | 40 | 42 | 38 | 35 | 31 | 45 | 9.20 |
| 07:00 | 043 | 39 | 40 | 35 | 32 | 30 | 30 | ---- |
| 08:00 | 000 | 38 | 39 | 33 | 30 | 29 | 20 | ---- |

The Table 1 shows the variation of intensity, temperature, and yield along with the efficiency with respect to time at 1 cm water depth. The Figure 5 shows the variation of efficiency and solar radiation with respect to time at 1 cm depth of water.

Table 2

| Time | I | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | Yield | Efficiency |
|---|---|---|---|---|---|---|---|---|
| Hr | w/m2 | °C | °C | °C | °C | °C | Ml | % |
| 08:00 | 833 | 29 | 28 | 31 | 32 | 30 | 00 | 00 |
| 09:00 | 972 | 32 | 33 | 33 | 34 | 31 | 15 | 2.07 |
| 10:00 | 1017 | 35 | 36 | 34 | 35 | 32 | 25 | 3.28 |
| 11:00 | 1083 | 40 | 42 | 39 | 40 | 33 | 40 | 4.91 |
| 12:00 | 1123 | 48 | 50 | 45 | 45 | 35 | 60 | 7.04 |
| 01:00 | 1157 | 58 | 61 | 55 | 54 | 37 | 70 | 7.89 |
| 02:00 | 1135 | 56 | 57 | 53 | 51 | 37 | 80 | 5.23 |
| 03:00 | 1010 | 50 | 54 | 52 | 48 | 36 | 75 | 9.75 |
| 04:00 | 923 | 49 | 52 | 51 | 43 | 34 | 60 | 8.55 |
| 05:00 | 753 | 47 | 49 | 49 | 37 | 33 | 55 | 9.64 |
| 06:00 | 550 | 44 | 48 | 46 | 33 | 31 | 40 | 9.61 |
| 07:00 | 025 | 41 | 45 | 43 | 30 | 29 | 30 | ---- |
| 08:00 | 000 | 40 | 43 | 41 | 29 | 28 | 20 | ---- |

The Table 2 shows the variation of intensity, temperature, and yield along with the efficiency with respect to time at 2 cm water depth. The Figure 6 shows the variation of efficiency and solar radiation with respect to time at 1 cm depth of water.

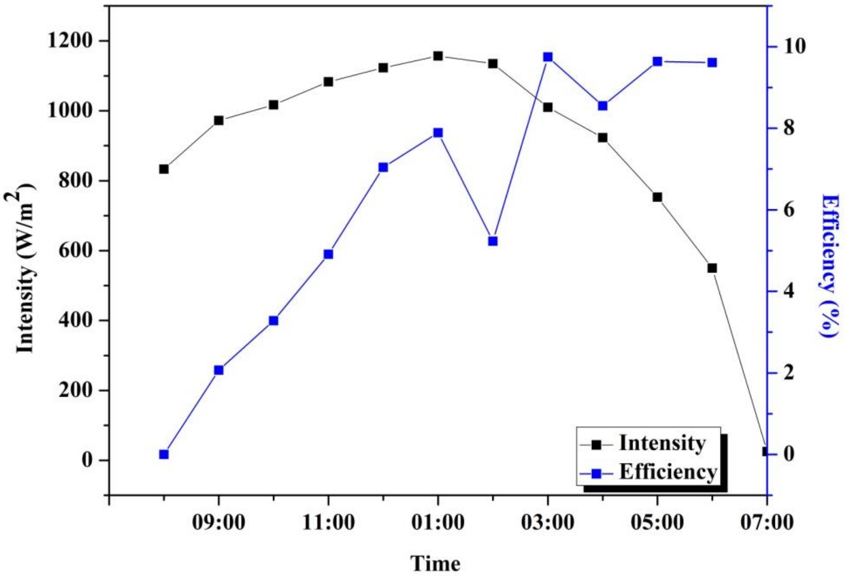


Figure 6 Variation of efficiency and solar radiation with respect to time at 2 cm depth of water

## V CONCLUSION

In this investigation, 5 double slope single basin passive solar stills are used with different storage materials in three of the still and water is used in two stills i.e. a conventional still and non-conventional. The following observations have been noted during the experiment and by the analysis of results and graphs.

- The maximum yield is obtained from jute with water 880 at 1 cm depth of water, which is 2.3% more that yield obtained by using granite, 4.7% more than the yield obtained from aluminum, 39.68% more than the yield of conventional still with saline water and 46.67 % more than the yield observed from non-conventional still with saline water.
- The maximum efficiencies for each material are observed as, 10.17% by using conventional still with saline water at 1 PM and 1cm, 10.37% using non-conventional still at 2 PM and 1 cm, 15.52% using aluminum pieces at 6 PM and 3cm, 15.58% using granite at 6PM and 3 cm and 15.69% using jute at 6PM and 3 cm depth of water.
- In terms of efficiency, it is observed that the overall maximum efficiency is obtained by using jute is 15.69% which is 0.7% higher than the calculated efficiency of granite, 1.09% more than the efficiency obtained from aluminum pieces with saline water, 54.27% higher than the yield of conventional still using water and 33.9% more than the non-conventional still with saline water.
- So, it can be concluded that the jute is optimized storage material for the production of pure water by using single basin double slope passive solar still.

## VI. ACKNOWLEDGMENT

The author(s) are thankful to Sagar Institute of Science and Technology for providing necessary faciltity to carry out this study..

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